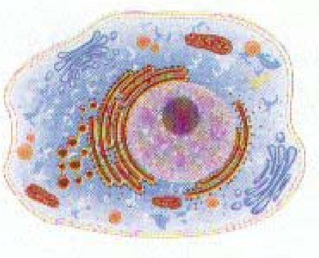
AS Biology - Module 1



CHAPTER 1:
STRUCTURE AND FUNCTION
OF THE CELL

INTRODUCTION TO THE CELL

Both living and non-living things are composed of molecules made from chemical elements such as Carbon, Hydrogen, Oxygen, and Nitrogen. The organization of these molecules into cells is one feature that distinguishes living things from all other matter. **The cell is the smallest unit of matter that can carry on all the processes of life.**

FIGURE 3.2
Robert Hooke's drawings of cork seen through a microscope show rows of empty spaces. What did he call these spaces? 2

1. Every living thing - from the tiniest bacterium to the largest whale - is made of one or more cells.
2. Before the C17th, no one knew that cells existed, since they are too small to be seen with the naked eye. The invention of the microscope enabled Robert Hooke, (1665) and Anton van Leuwenhoek (1675) to see and draw the first 'cells', a word coined by Hooke to describe the cells in a thin slice of cork, which reminded him of the rooms where monks lived.
3. The idea that **all** living things are made of cells was put forward in about 1840 and in 1855 came 'Cell Theory' – i.e. 'cells only come from other cells' – contradicting the earlier theory of 'Spontaneous Generation'

Cell Theory consists of **three** principles:

a. All living things are composed of **one or more cells.**
b. Cells are the **basic units of structure and function** in an organism.
c. Cells come only from the **replication of existing cells.**

CELL DIVERSITY

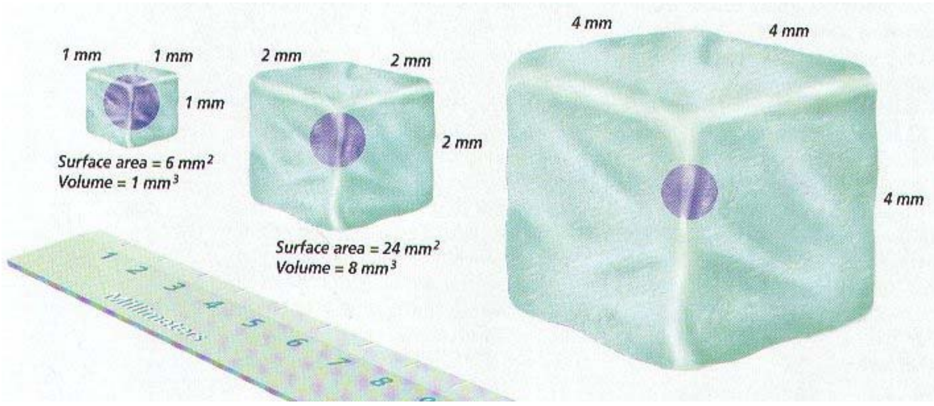
Not all cells are alike. Even cells within the same organism show enormous diversity in size, shape, and internal organization. Your body contains around 10^{13} to 10^{14} cells of around 300 different cell types, which we broadly classify into 4 groups.

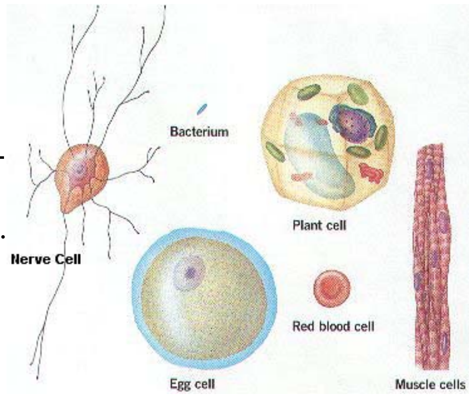
CELL SIZE

1. A few types of cells are large enough to be seen by the unaided eye. The human egg (ovum) is the largest cell in the body, and can (just) be seen without the aid of a microscope.
2. Most cells are small for **two** main reasons:

a). The cell's nucleus can only control a certain volume of active cytoplasm.
b). Cells are limited in size by their **surface area to volume ratio**. A group of small cells has a **relatively larger surface area** than a single large cell of the same volume. This is important because the nutrients, oxygen, and other materials a cell requires must enter through it surface. As a cell grows larger at some point its surface area becomes too small to allow these materials to enter the cell quickly enough to meet the cell's need. (= ***Fick's Law*** – *something you need to learn* ***well*****).**

$$\textbf{Rate of diffusion} \quad \alpha \quad \frac{\textbf{Surface Area x Concentration Difference}}{\textbf{Distance}}$$



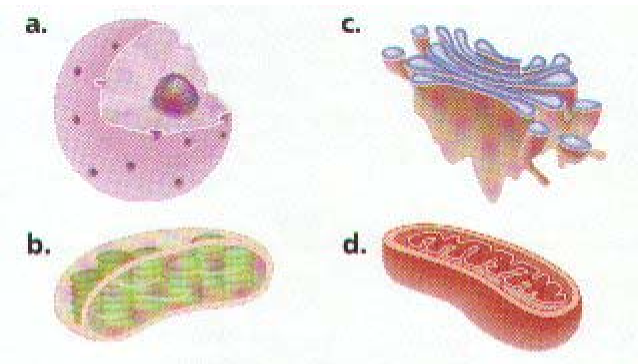


CELL SHAPE

Cells come in a variety of shapes – depending on their function:-
The neurones from your toes to your head are long and thin;
Blood cells are rounded disks, so that they can flow smoothly.

INTERNAL ORGANIZATION

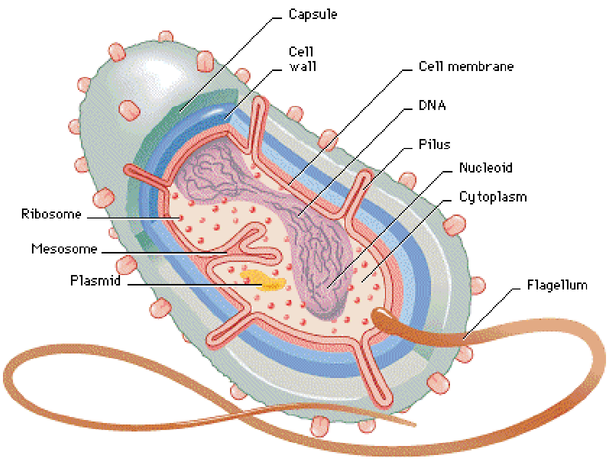
1. Cells contain a variety of internal structures called **organelles.**



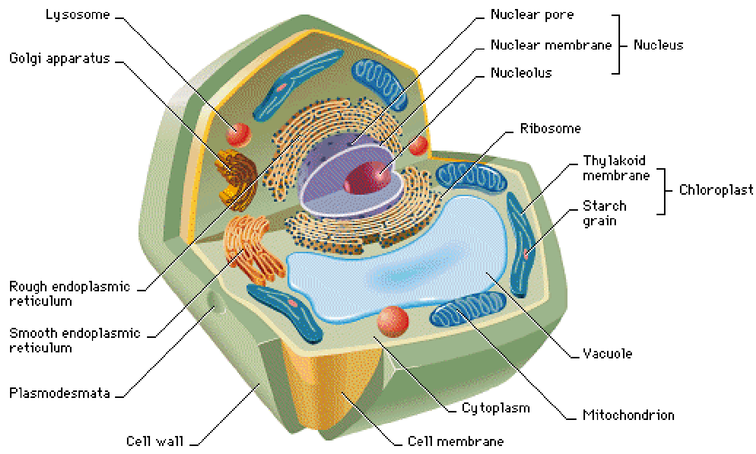
2. An organelle is a cell component that **performs a specific function in that cell.**
3. Just as the organs of a multicellular organism carry out the organism's life functions, the organelles of a cell maintain the life of the cell.
4. There are many different cells; however, there are certain features common to all cells.
5. The entire cell is surrounded by a thin **cell membrane**. All membranes have the same thickness and basic structure.
6. Organelles often have their own membranes too – once again, these membranes have a similar structure.
7. The **nucleus, mitochondria** and **chloroplasts** all have **double membranes,** more correctly called **envelopes.**
8. Because membranes are **fluid mosaics,** the molecules making them up – **phospholipids** and **proteins -** move independently. The proteins appear to 'float' in the phospholipids bilayer and thus membranes can thus be used to transport molecules **within** the cell e.g. **endoplasmic reticulum.**
9. **Proteins** in the membrane can be used to transport substances **across** the membrane – e.g. by **facilitated diffusion** or by **active transport.**
10. The proteins on the outside of cell membranes **identify us as unique.**

Prokaryotes v. Eukaryotes

Organisms whose cells normally contain a nucleus are called **Eukaryotes;** those (generally smaller) organisms whose **cells lack a nucleus** and **have no membrane-bound organelles** are known as **Prokaryotes.**



A Prokaryotic cell (bacterium)



A Eukaryotic cell (plant)

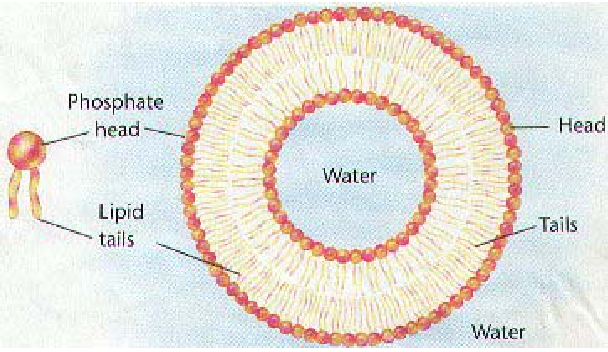
	Prokaryotes	**Eukaryotes**
Typical organisms	bacteria	Protoctista, fungi, plants, animals
Typical size	~ 1-10 µm	~ 10-100 µm (sperm cells) apart from the tail, are smaller)
Type of nucleus	Nuclear body **No nucleus**	real nucleus with nuclear envelope
DNA	circular (ccc DNA)	linear molecules (chromosomes) with histone proteins
Ribosomes	70S	80S
Cytoplasmatic structure	very few structures	highly structured by membranes and a cytoskeleton
Cell movement	Flagellae/cilia made of flagellin	flagellae and cilia made of tubulin
Mitochondria	none	1 - 100 (though RBC's have none)
Chloroplasts	none	in algae and plants
Organization	usually single cells	single cells, colonies, higher multicellular organisms with specialized cells
Cell division	Binary fission (simple division)	Mitosis (normal cell replication) Meiosis (gamete production)

PARTS OF THE EUKARYOTIC CELL

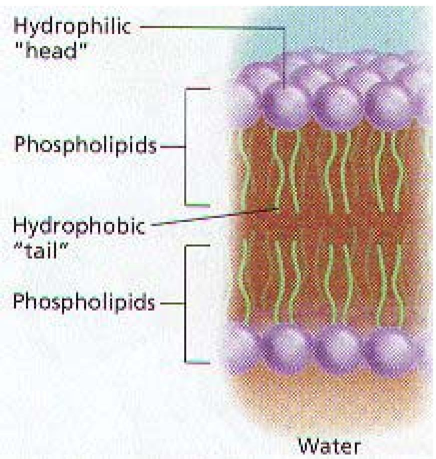
The structures that make up a Eukaryotic cell are determined by the specific functions carried out by the cell. Thus, there is **no** typical Eukaryotic cell. Nevertheless, Eukaryotic cells generally have **three** main components: A cell membrane, a nucleus, and a variety of other organelles.

THE CELL MEMBRANE

1. A cell cannot survive if it is totally isolated from its environment. The cell membrane is a complex barrier separating every cell from its external environment.
2. This "Selectively Permeable" membrane regulates what passes into and out of the cell.
3. The cell membrane is a **fluid mosaic** of **proteins** floating in a **phospholipid bilayer.**

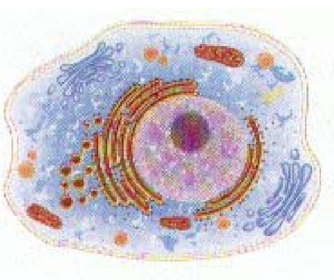


4. The cell membrane functions like a gate, controlling which molecules can enter and leave the cell.
5. The cell membrane controls which substances pass into and out of the cell. **Carrier proteins** in or on the membrane are specific, only allowing a small group of **very** similar molecules through. For instance, α- glucose is able to enter; but β – glucose is not. Many molecules cannot cross **at all**. For this reason, the cell membrane is said to be **selectively permeable.**
6. The rest of the cell membrane is mostly composed of **phospholipid molecules**. They have only **two fatty acid 'tails'** as one has been replaced by a **phosphate group** (making the **'head')**



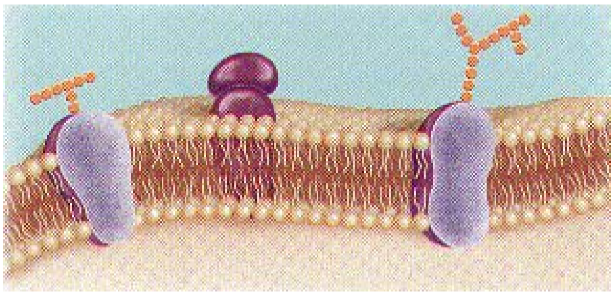
7. The head is charged and so polar; the tails are not charged and so are non-polar. Thus the two ends of the phospholipid molecule have different properties in water. The phosphate head is **hydrophyllic** and so the head will orient itself so that it is as close as possible to water molecules. The fatty acid tails are **hydrophobic** and so will tend to orient themselves **away** from water.
8. So, when in water, phospholipids line up on the surface with their phosphate heads sticking **into** the water and fatty acid tails pointing up from the surface.
9. Cells are bathed in an aqueous environment and since the inside of a cell is also aqueous, both sides of the cell membrane are surrounded by water molecules.
10. This causes the phospholipids of the cell membrane to form **two** layers, known as a **phospholipid bilayer.** In this, the heads face the watery fluids inside and outside the cell, whilst the fatty acid tails are sandwiched inside the bilayer.
11. The cell membrane is constantly being formed and broken down in living cells.

CYTOPLASM



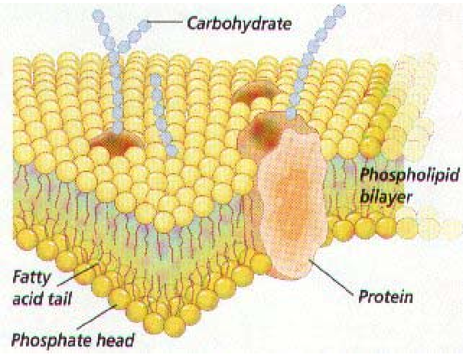
1. Everything within the cell membrane which is not the nucleus is known as the **cytoplasm**.
2. **Cytosol** is the jelly-like mixture in which the other organelles are suspended, so **cytosol + organelles = cytoplasm**.
3. **Organelles** carry out specific functions within the cell. In Eukaryotic cells, most organelles are surrounded by a **membrane**, but in Prokaryotic cells there are **no membrane-bound organelles.**

FLUID MOSAIC MODEL OF CELL MEMBRANES



1. Membranes are **fluid** and are rather viscous – like vegetable oil.
2. The molecules of the cell membrane are always in motion, so the phospholipids are able to drift across the membrane, changing places with their neighbour.
3. Proteins, both in and on the membrane, form a **mosaic,** floating in amongst the phospholipids.
4. Because of this, scientists call the modern view of membrane structure the '**Fluid Mosaic Model**'.
6. The mosaic of proteins in the cell membrane is constantly changing.

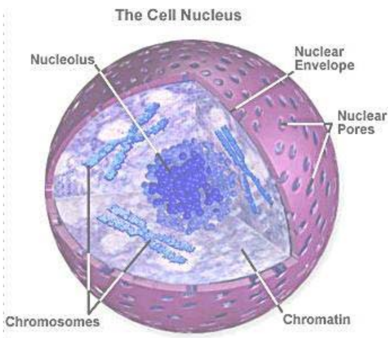
MEMBRANE PROTEINS



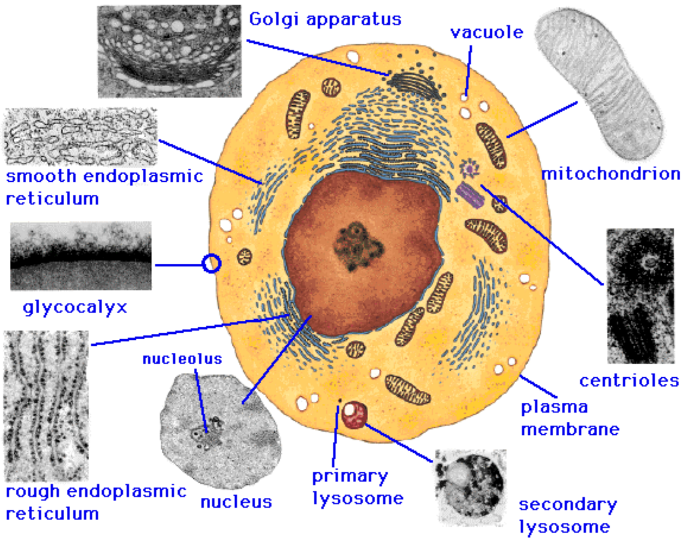
1. A variety of protein molecules are embedded in the basic phospholipid bilayer.
2. Some proteins are attached to the surface of the cell membrane on both the internal and external surface. These may be hormone receptors, enzymes or cell recognition proteins (or antigens)
3. Other proteins are embedded in the phospholipid bilayer itself. These are often associated with transporting molecules from one side of the membrane to the other and are referred to as **carrier proteins.**
4. Some of these form channels or pores through which certain substances can pass (**facilitated diffusion**), whilst others bind to a substance on one side of the membrane and carry it to the other side of the membrane (**active transport**)
5. Proteins exposed to the cell's external environment often have carbohydrates attached to them which act as antigens (e.g. blood groups A & B – group AB has **both**; group O has **neither**).
6. Some viruses may also bind here too.

THE NUCLEUS (pl. NUCLEI)

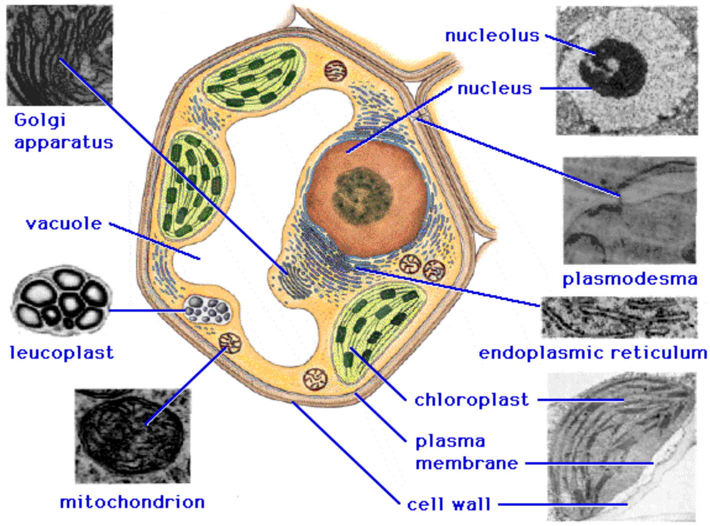
1. The nucleus is normally the largest organelle within a Eukaryotic cell. But it is **NOT** the **'brain'** of the cell!!
2. Prokaryotes have **no nucleus**, having a **nuclear body** instead. This has **no membrane** and a **loop of DNA** - cccDNA - and no chromatin proteins)
3. The nucleus contains the cell's chromosomes (human, 46, fruit fly 6, fern 1260) which are normally uncoiled to form a **chromatinic network,** which contain both **linear DNA** and proteins, known as **histones**. These proteins coil up (dehydrate) at the start of nuclear division, when the chromosomes first become visible.



4. Whilst most cells have a single nucleus some cells (macrophages, phloem companion cells) have more than one and fungi have many nuclei in their cytoplasm – they are **coenocytic** (= common cytoplasm throughout)
5. The nucleus is surrounded by a **double membrane** called the **nuclear envelope**, which has many **nuclear pores** through which **mRNA**, and **proteins** can pass. These dimples make it look like a golf ball.
6. Most nuclei contain at least one **nucleolus** (plural, nucleoli). The nucleoli are where **ribosomes** are synthesised. Ribosomes, you remember, translate mRNA into proteins.
7. When a nucleus prepares to divide, the nucleolus disappears.



An animal cell

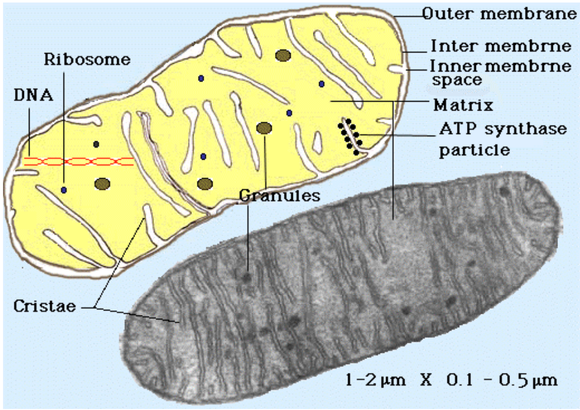


A plant cell

Comparison of structures between animal and plant cells

	Typical animal cell	Typical plant cell
Organelles	• ○ Nucleolus *(within nucleus)* • Rough ER • Smooth ER • 80S Ribosomes • Cytoskeleton • Golgi apparatus • Cytoplasm • Mitochondria • Vesicles • Vacuoles • Lysosomes • Centrioles	• ○ Nucleolus *(within nucleus)* • Rough ER • Smooth ER • 80S Ribosomes • Cytoskeleton • Golgi apparatus • Cytoplasm • Mitochondrion • Vesicle • Chloroplast and other plastids • ○ Tonoplast *embrane*)
Additional structures	• Flagellae • Plasma membrane	• Cellulose cell wall • Plasmodesmata

MITOCHONDRIA



1. Mitochondria are found scattered throughout the cytosol, and are relatively large organelles (second only to the nucleus and chloroplasts).
2. Mitochondria are the sites of **aerobic respiration,** in which energy from organic compounds is transferred to ATP. For this reason they are sometimes referred to as the 'powerhouse' of the cell.
3. ATP is the molecule that most cells use as their main energy 'currency'.
4. Mitochondria are more numerous in cells that have a high energy requirement - our muscle cells contain a large number of mitochondria, as do liver, heart and sperm cells.
5. Mitochondria are surrounded by **two** membranes, indicating that they were once free-living organisms that have become mutualistic and then a part of almost every eukaryotic cell (not RBC's and xylem vessels)
   A. The smooth outer membrane serves as a boundary between the mitochondria and the cytosol.
   B. The inner membrane has many long folds, known as **cristae,** which greatly increase the surface area of the inner membrane, providing more space for ATP synthesis to occur.
6. Mitochondria have their own DNA, and new mitochondria arise only when existing ones grow and divide. They are thus **semi-autonomous organelles.**

RIBOSOMES

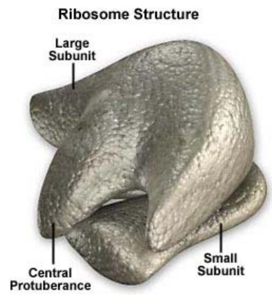
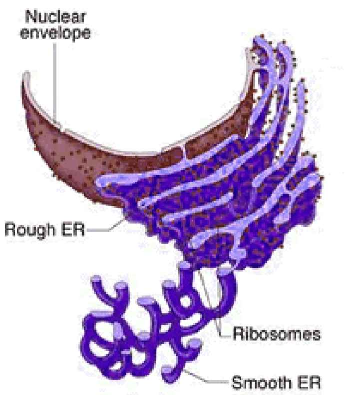


Figure 1

1. Unlike most other organelles, ribosomes are not surrounded by a membrane.
2. Ribosomes are the site of **protein synthesis** in a cell.
3. They are the most common organelles in almost all cells.
4. Some are free in the cytoplasm (Prokaryotes); others line the membranes of **rough endoplasmic reticulum** (rough ER).
5. They exist in **two sizes**:
   70s are found in all Prokaryotes, chloroplasts and mitochondria, suggesting that they have evolved from ancestral Prokaryotic organisms. They are free-floating.
   80s found in all eukaryotic cells – attached to the rough ER (they are rather larger).
6. Groups of 80s ribosomes, working together, are known as a **polysome.**

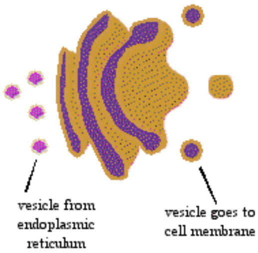
ENDOPLASMIC RETICULUM (ER)

1. The ER is a system of membranous tubules and sacs.
2. The primary function of the ER is to act as an internal transport system, allowing molecules to move from one part of the cell to another.



3. The quantity of ER inside a cell fluctuates, depending on the cell's activity. Cells with a lot include secretory cells and liver cells.
4. The **rough ER** is studded with **80s ribosomes** and is the site of **protein synthesis**. It is an extension of the outer membrane of the nuclear envelope, so allowing mRNA to be transported swiftly to the 80s ribosomes, where they are translated in protein synthesis.
5. The **smooth ER** is where polypeptides are converted into functional proteins and where proteins are prepared for secretion. It is also the site of lipid and steroid synthesis, and is associated with the Golgi apparatus. **Smooth ER** has no 80s ribosomes and is also involved in the regulation of calcium levels in muscle cells, and the breakdown of toxins by liver cells.
6. **Both types of ER transport materials throughout the cell.**

GOLGI APPARATUS



1. The Golgi apparatus is the processing, packaging and secreting organelle of the cell, so it is much more common in glandular cells.
2. The Golgi apparatus is a system of membranes, made of flattened sac-like structures called **cisternae.**
3. It works closely with the smooth er, to modify proteins for export by the cell.

LYSOSOMES

1. Lysosomes are small spherical organelles that enclose hydrolytic enzymes within a single membrane.
2. Lysosomes are the site of protein digestion – thus allowing enzymes to be re-cycled when they are no longer required. They are also the site of food digestion in the cell, and of bacterial digestion in **phagocytes**.
3. Lysosomes are formed from pieces of the Golgi apparatus that break off.
4. Lysosomes are common in the cells of Animals, Protoctista and even Fungi, but rare in plants.

CYTOSKELETON

1. Just as your body depends on your skeleton to maintain its shape and size, so a cell needs structures to maintain its shape and size.
2. In animal cells, which have no cell wall, an internal framework called the **cytoskeleton** maintains the shape of the cell, and helps the cell to move.
3. The cytoskeleton consists of **two** structures:
   a) **microfilaments** (contractile). They are made of actin, and are common in motile cells.
   b) **microtubules** (rigid, hollow tubes – made of tubulin).
4. Microtubules have **three functions:**
   a. To maintain the shape of the cell.
   b. To serve as tracks for organelles to move along within the cell.
   c. They form the **centriole.**

CENTRIOLE

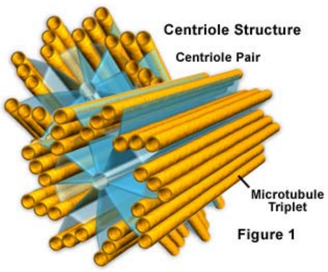
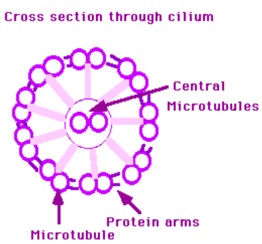


Figure 1

1. This consists of two bundles of microtubules at right-angles to each other.
2. Each bundle contains 9 tubes in a very characteristic arrangement
3. At the start of mitosis and meiosis, the centriole divides, and one half moves to each end of the cell, forming the spindle.
4. The spindle fibres are later shortened to pull the chromosomes apart.

CILIA AND FLAGELLAE

1. Cilia and Flagellae are structures that project from the cell, where they assist in movement.



2. **Cilia** (sing. **cilium**) are short, and numerous and hair-like.
3. **Flagellae** (sing. **flagellum**) are much longer, fewer, and are whip-like.
4. The cilia and flagellae of all Eukaryotes are always in a '9 + 2' arrangement that is characteristic (see diagram).
5. Protoctista commonly use cilia and flagellae to move through water.
6. Sperm use flagellae (many, all fused together) to swim to the egg.
7. Cilia line our trachea and bronchi, moving dust particles and bacteria away from the lungs.

PLANT CELL STRUCTURES

1. Most of the organelles and other parts of the cell are common to **all** Eukaryotic cells. Cells from different organisms have an even greater difference in structure.
2. Plant cells have **three** additional structures not found in animal cells:
- **Cellulose cell walls**
- **Chloroplasts** (and other plastids)
- **A central vacuole.**

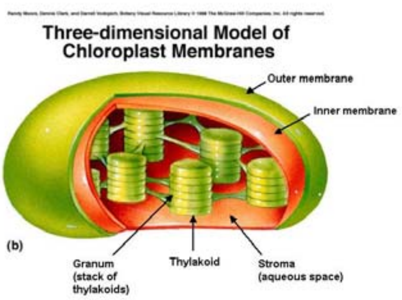
CELLULOSE CELL WALL
1. One of the most important features of **all** plants is presence of a **cellulose cell wall**.
2. Fungi such as Mushrooms and Yeast also have cell walls, but these are made of **chitin**.
3. The cell wall is **freely permeable** (porous), and so has no direct effect on the movement of molecules into or out of the cell.
4. The rigidity of their cell walls helps both to **support** and **protect** the plant.
5. Plant cell walls are of **two types:**

a). **Primary (cellulose) cell wall** - While a plant cell is being formed, a **middle lamella** made of pectin, is formed and the cellulose cell wall develops between the middle lamella and the cell membrane. As the cell expands in length, more cellulose is added, enlarging the cell wall. When the cell reaches full size, a secondary cell wall **may** form.

b). **Secondary (lignified) cell wall** - The secondary cell wall is formed only in woody tissue (**mainly xylem**). The secondary cell wall is stronger and waterproof and once a secondary cell wall forms, a cell can grow no more – it is dead!

VACUOLES
1. The most prominent structure in plant cells is the **large vacuole**.
2. The vacuole is a large membrane-bound sac that fills up much of most plant cells.
3. The vacuole serves as a **storage area**, and may contain stored **organic molecules** as well as **inorganic ions**.
4. The vacuole is also used to store waste. Since plants have no kidney, they convert waste to an insoluble form and then store it in their vacuole - until autumn!
5. The vacuoles of some plants **contain poisons** (eg tannins) that discourage animals from eating their tissues.
6. Whilst the cells of other organisms may also contain vacuoles, they are much smaller and are usually involved in food digestion.

CHLOROPLASTS (and other plastids)
1. A characteristic feature of plant cells is the presence of **plastids** that make or store food.



2. The most common of these (**some leaf cells only!**) are **chloroplasts** – the site of **photosynthesis.**
3. Each chloroplast encloses a system of flattened, membranous sacs called **thylakoids,** which contain **chlorophyll**.
4. The thylakoids are arranged in stacks called **grana.**
5. The space between the grana is filled with cytoplasm-like **stroma.**
6. Chloroplasts contain **ccc DNA** and **70S ribosomes** and are **semi-autonomous organelles**.
7. Other plastids store reddish-orange pigments that colour petals, fruits, and some leaves.

MULTICELLULAR ORGANIZATION

In a unicellular organism, one cell carries out all of the functions of life. In contrast, most cells in a multicellular organism are specialized to perform one or a few functions – more efficiently. Because of cell specialization, the cells of multicellular organisms depend on other cells in the organism for their survival.

TISSUE, ORGANS, AND ORGAN SYSTEMS

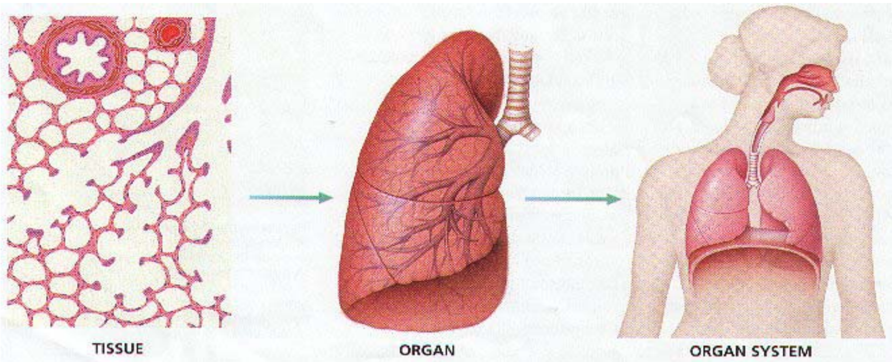
1. In most Multicellular Organisms, we find the following organization:

Cellular Level: The smallest unit of life capable of carrying out all the functions of living things.

Tissue Level: A group of cells that performs a specific function in an organism.

Organ Level: Several different types of tissue that function together for a specific purpose.

Organ System Level: Several organs working together to perform a function. The different organ systems in a multicellular organism interact to carry out the processes of life



2. Plants also have tissue and organs, although they are arranged somewhat differently from those of animals – e.g. vascular tissue.

3. The **four** plant organs are:

Roots
Stems
Leaves and
Flowers

COLONIAL ORGANIZATIONS

1. A colonial organization is a collection of genetically identical cells that live together in a closely connected group.
2. Many of the cells of the colony carry out specific functions that benefit the whole colony.
3. Colonial organisms (e.g. sponges, coral) appear to straddle the border between a collection of unicellular organisms and a true multicellular organism. They lack tissues and organs, but do exhibit the principle of cell specialization.

ORGANELLE	LOCATION	DESCRIPTION	FUNCTION
cell wall	plant, not animal	outer layer rigid, strong, stiff made of cellulose	support (grow tall) protection allows H_2O, O_2, CO_2 to pass into and out of cell
cell membrane	both plant/animal	plant - inside cell wall animal - outer layer; cholesterol selectively permeable	support protection controls movement of materials in/out of cell barrier between cell and its environment maintains homeostasis
nucleus	both plant/animal	large, oval	controls cell activities
nuclear membrane	both plant/animal	surrounds nucleus selectively permeable	Controls movement of materials in/out of nucleus
cytoplasm	both plant/animal	clear, thick, jellylike material and organelles found inside cell membrane	supports /protects cell organelles
endoplasmic reticulum (E.R.)	both plant/animal	network of tubes or membranes	carries materials through cell
ribosome	both plant/animal	small bodies free or attached to E.R.	produces proteins
mitochondrion	both plant/animal	bean-shaped with inner membranes	breaks down sugar molecules into energy
vacuole	plant - few/large animal - small	fluid-filled sacs	store food, water, waste (plants need to store large amounts of food)
lysosome	plant - uncommon animal - common	small, round, with a membrane	breaks down larger food molecules into smaller molecules digests old cell parts
chloroplast	plant, not animal	green, oval usually containing chlorophyll (green pigment)	uses energy from sun to make food for the plant (photosynthesis)